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# Operations Research: A Valuable Asset for the Operational Commander

by

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A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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## ABSTRACT

Operations research (O.R.) is a valuable tool to the operation commander which can aid him by providing a quantitative basis for decision making and problem solving; however, he must understand its strengths and limitations. This paper introduces the operator to those strengths and limitations.

The paper is oriented toward the operator in order to provide him or her insight as to the value of O.R. This is accomplished through a broad presentation of operations research concepts, Soviet viewpoints, explanations, and examples set in an operational context. Technical details are limited and the analyst is addressed only through the perspective of the operational commander and his analytical requirements.

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# CHAPTER 1

# BACKGROUND

## INTRODUCTION

No other job carries the awesome responsibility as that of the operational commander. He is a leader, a manager, and the ultimate decision maker. As a manager, he allocates resources to insure the maximum combat power is available at the decisive point in time and space to accomplish the mission. As a decision maker, he must chose the best course of action, realizing that his decisions ultimately determine the results of the operation and could determine the life or death of his subordinates. But the operational commander is more than a manager, he is a leader. He must inspire and earn the trust of those soldiers that place their confidence in him. A key ingredient in the development of this confidence is knowledge that the commander is making the best informed decisions possible and is executing those decisions appropriately. Bennis and Nanus in their book, Leaders, state, "Managers do things right. Leaders do the right thing."[1] Operational commanders must do both. Operations research can greatly aid the operational commander, if he understands its strengths and limitations. It can help the commander plan, direct, and execute his operations.

## DEFINITION

The question, what is operations research (O.R.), must be answered. Morse and Kimball provided an early definition: "Operations research is a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control."[2] Harvey Wagner stated that operations research is, "a scientific method to problem solving."[3] The key words in these definitions are operations, decisions, problem solving, and quantitative. Putting these words in the context of the operational commander: Operations research is a method for problem solving which provides the commander a quantitative basis for operational decisions. This is not to mean that a commander's decisions should be based solely on the computer output of a mathematical model. Rather his decision making and problem solving capability can be enhanced through the proper analysis of quantitative models. The quantitative analysis must be technically correct, but just as important, it must be reviewed in the context of reality. The analyst is responsible for applying sound judgement and common sense to the mathematical solution. Combining the power of a quantitative basis with real experience and common sense is the key to successful application of operations research. This raises possibly the best definition for O.R.: - mathematical common sense.

## SCOPE

This paper will show how operations research can aid the operational commander, provided he understands its strengths and limitations. The scope will be limited to operational problem solving. In many instances, operations research is thought of in the context of cost analysis, strategic planning, or large scale force on force computer models; however, those types of operations research applications will not be discussed. Instead, this paper will discuss, from a broad perspective, some of the analytical tools available to the operational commander. It will not attempt to cover all "types" of problems, rather it will give some specific simple examples to acquaint the operator with the power, value and limitations of O.R. The paper's technical level is again geared towards the operator and not the analyst. It is designed for the analyst only in the context to identify what the operational commander/decision maker "really needs" from him.

## ORGANIZATION

This paper is organized into five chapters. First, there is a brief look at history citing applications of operations research in World War II and the Falklands. Next, the value of operations research is discussed and several examples of "types" of problems which could aid the operational commander are presented. Techniques for resource allocation and decision making are illustrated and the Soviet view of O.R. is explained. This is followed by the pitfalls and limitations for using operations research. Included in this chapter are the possible effects imposed by taking quantitative analysis to the extremes. The last chapter provides conclusions by addressing what the commander should ask for and expect from the O.R. analyst, and conversely, what the analyst needs to provide to the operational decision maker.

# CHAPTER 2

## HISTORY

Quantitative modeling techniques have helped people understand complex concepts and have aided in the decision making process for years. The actual field of operations research largely has its developmental roots in the military during World War II. Operations research was born, as its name implies, through the study and research of military operations. "Because of the war effort, there was an urgent need to allocate scarce resources to the various military operations and to the activities within each operation in an effective manner."[4] The application of scientific principles to operational problems helped the allied effort immensely. Admiral King, in his Final Report, December, 1945, stated the valuable contributions that operations research had made to the war effort. "The complexity of modern warfare ... demands exacting analysis.... The application ... of the scientific method to the improvement of naval operating techniques ... has come to be called operations research. Scientists engaged in operations research are experts who advise that part of the Navy which is using the weapons and craft - the fleets themselves."[5] In today's terminology, it can be clearly interpreted that King referred to the effects of operations research at the operational level of war.

To cite a specific example, Morse and Kimball in their book, Methods of Operations Research, describe several uses of operations research in World War II. A relatively simple application, but one which had a major influence on the conduct of operations, was the decision to enlarge the size of sea-going convoys. By gathering data on ships sunk by U-Boat activity, researchers were able to determine that the number of vessels sunk by U Boats was independent of the number of vessels in the convoy. In other words, the same number of ships were lost no matter the size of the convoy. The percentage of ships lost per convoy was less in the larger convoy, thus it was "cost effective" to operate with larger convoys. In the same analysis of convoy operations in the North Atlantic during 1941 and 1942, it was determined that the number of ships lost was directly proportional to the number of allied escort ships accompanying the convoy. Since more escort ships meant less tonnage lost, this could have easily evolved into a resource allocation problem of escort ships (the allocation problem-type will be addressed in the next chapter).

In a point in history closer to current day applications, the British made good use of operations research during the Falkland Islands Campaign. They used O.R. to access the Argentine mine threat, to develop counter measures for the exocet missile threat, and to design logistical support operations. After action reports indicate that the British would also prefer to have an "on-scene" operations research capability to aid in operational problem solving in future conflicts.[6]

With the advancement in technologies and the incorporation of computers in every facet of military activity, the ability to apply operations research has expanded. Computers allow for quantitative analysis of problems which heretofore were considered too difficult or too time consuming for quantitative solutions. The application of operations research has come a long way but the purposes for O.R. remain the same; to provide the decision maker a quantitative basis for problem solving and decision making.

# CHAPTER 3

## STRENGTHS AND VALUE OF OPERATIONS RESEARCH

As seen in the preceding chapter, there have been many uses for operations research in past conflicts. This chapter continues to discuss the value of O.R. at the operational level of war and demonstrates specific types of problem solving which could aid the operational commander.

### VALUE OF OPERATIONS RESEARCH FROM THE SOVIET VIEWPOINT

The Soviets view military operations and the "practice of war" as a science. Operations research is embedded in the very nature of Soviet operations and is consistent with strict theoretical structures which govern Soviet military thinking. They believe that "in order to make a timely, sound decision, it is very important for the commander to use ... mathematical methods."[7] In the Soviet commanders decision process, he must perform a process called "optimization of the decision"[8] which is a quantitative substantiation of the selected course of action to insure the most effective use of men and equipment. The Soviets believe that this process "lifts" the commander's decision to fit within the framework of "natural" laws. In his book, Fundamentals of Tactical Command and Control (translated from Russian), Ivanov discusses several areas of operations in which quantitative calculations are applied. They include: the combat capabilities (combat and combat support) of all belligerents, force correlations, troop movement and logistical support, and possible combat losses. Pre determined algorithms are established determining the relationships among the variables used in these calculations. During the analysis of opposing courses of actions, appropriate variable coefficients are determined, thus allowing quantification of an operational problem. Ivanov uses an example which explains how the Soviets might calculate the expected number of aircraft to be destroyed in an operation:

"$M_o = N_o + T_{fir} + P_{hit} + K_{cont} + K_{part}$

where

$M_o$ = the mathematical expectation of the number of aircraft downed;

$N_o$ = the number of available antiaircraft weapon types in the given version of their grouping;

$T_{fir}$ = the number of rounds which can be produced by each weapon type in one enemy attack;

$P_{hit}$ = the probability of downing an enemy aircraft with one weapon type in one round;

$K_{cont}$ = the reliability coefficient of the fire control system;

$K_{part}$ = the coefficient of participation of the available weapon types in repelling enemy aircraft."[9]

From these calculations, the commander could determine the required correlation of forces required for the operation. Although there is a requirement for all officers to understand and possess the capability to perform the quantitative analysis, the Soviet system provides for a corps of officers and NCOs that are experts in the field.

## STRENGTHS OF OPERATIONS RESEARCH

Unlike the Soviets, the United States military views operations more as an art rather than a science. Operations research is not embedded in U.S. doctrine. FM 100-5 states that "Operational art ... involves fundamental decisions about where and when to fight and whether to accept or decline battle."[10] It also states that operational art requires the commander answer three questions:

> (1) What military condition must be produced in the theater of war or operations to achieve the strategic goal?
>
> (2) What sequence of actions is most likely to produce that condition?
>
> (3) How should the resources of the force be applied to accomplish that sequence of actions?[11]

Operations research can help the commander answer those questions and aid in making the tough decisions. The strengths and value of O.R. lay in problem solving and decision making support.

### A. DECISION ANALYSIS

Problem solving and decision making are strongly related. In both instances a person must recognize the need to improve a situation or recognize the chance of failure to meet an objective. In other words, one must identify and define the problem that exists. Once the problem is defined, then the problem solution identifies and analyzes the possible alternatives that will meet the intended objective. In this context, all problems eventually require a decision. A decision is the choice between one or more courses of action. Operations research provides the quantitative basis for the selection of a particular course of action.

Decisions are made in all facets of operations (as well as everyday life) and the type of decision made is situational. In other words, how a person makes a decision depends upon the situation and the amount of information available to the decision maker. There are three types of decision situations which are classified based on the available information:

(1) Decision under Certainty - complete information is available.

(2) Decision under Risk - partial information is available. The outcome is probabalistic and the decision is based on the "chance" of the outcome.

(3) Decision under Uncertainty - information is limited. The decision maker can not estimate the probability of the outcome.[12]

The operational commander must make decisions in all three types of decision situations.

There is a logical process to decision making which incorporates the availability of information.

(1) Define the problem.

"(2) Consider the alternatives ... and the possible uncertainties concerning the anticipated consequences. ...

(3) Probabilities ... are assigned, either objectively or else through the decision maker's (or an expert's) subjective judgement. ...

(4) Evaluate the results in light of the criterion of choice.

(5) Make the decision."[13]

The process above was taken from a non-military source, yet remarkably it is consistent with the process used in the commander's estimate. In accordance with NWP 11, the commander's estimate process includes in part: derive the mission, identify own courses of action, analyze and compare own courses of action (which includes determination of a measure of effectiveness), and formulate a decision.[14] Operations research quantifies this process.

Decision making models help the decision maker display the available information and quantify the analysis of competing alternatives. The type of decision model and criterion to be used for evaluation is dependent upon the decision situation (ie: certainty, risk, or uncertainty).

Under the conditions of certainty, the alternative analysis can be done by complete enumeration of all possible alternatives or through use of a mathematical model (An example of a decision under certainty is the resource allocation problem which is presented in the next section along with the linear programming algorithm).

As mentioned earlier, for decisions under risk, there is some information available and the nature of the decision is based on the probability of the outcome. The probabilities associated with the possible outcomes can be of two types, objective or subjective. Objective probabilities are based on historical/empirical knowledge or experimentation. They are an "actual, countable, observable fact."[15] For example, the probability of kill ($P_K$) or probability of hit ($P_H$) of a weapon on target can be obtained through experimentation. These would be considered objective probabilities for a decision entailing the selection of type of ordinance for a target. On the other hand, subjective probabilities are judgments on the probability of outcomes based on "expert" opinion. For example, a person with experience in operational planning may expect to lose ten percent of his aircraft given a particular course of action. He could apply a 0.90 probability that all aircraft would return safely. Selecting the best course of action for a decision under risk can use several "principles" of decision, however the most accepted criterion is "expected value". The expected value principle allows for the decision maker to make his choice based upon the alternative that has the greatest "expected" payoff or benefit. This is done by summing the values of all the possible payoffs and multiplying it by the probability that it will occur. For example, if Tank #1 had a $P_K$ of .90 and could engage five opposing tanks, the expected value of the outcome would be .9(1+1+1+1+1) = 4.5. If Tank #2 had a $P_K$ of .70 but could engage six opposing tanks, its expected value would be .7(1+1+1+1+1+1) = 4.2. Assuming the decision maker's measure of effectiveness was the number of opposing tanks killed, he would select Tank #1 over Tank #2 for the engagement (4.5 is greater than 4.2). There are several other principles-of-decision which could be used in decisions under risk to include: "expectation-variance" (used when a consistent payoff is more important than the size of the payoff), and "aspiration level" (used when the decision maker has a certain level of payoff that he wants to achieve and wants to maximize the probability of achieving it). Many of the decisions facing the operational commander will be those of the type that are under risk. In operational planning, he will rarely have complete information allowing a decision under certainty. Most likely, he will have intelligence information, data on friendly forces and equipment, and additional information on which he can formulate objective and subjective probabilities. The decision would be made under risk. If the decision maker can not estimate the probabilities, he must make the decision under uncertainty. The principles-of-decision to choose the best alternative include: Minimax or maximin, minimin or maximax, Laplace, and Hurwicz $\alpha$. The selection of criterion is dependent upon the decision to be made and the personality of the decision maker. If the decision maker is risk-adverse, maximin or minimax would be selected. It is the pessimistic approach which attempts to make the worst case outcome as desirable as possible. The converse is minimin or maximax. This is considered the optimistic approach and is for the decision maker willing to accept greater risk. Here the attempt is to maximize the best possible outcome or select the course of action that minimizes the minimum possible loss/cost. The Laplace criterion allows for all uncertain outcomes to have the same probability of occurrence and the decision maker would select the alternative with the best expected outcome. The Hurwicz principle attempts to soften the extremes of maximax and maximin.

The last item of discussion for decision analysis is the concept of "dominance". During the analysis of the courses of action, the analyst may determine that one alternative is better than another for all possible outcomes. That alternative is said to have the dominance over the lesser alternative. This is important because the decision maker can immediately remove that course of action from consideration.

Perhaps the best method to explain the difference in selecting a principle-of-decision by which to analyze alternatives is through an example. The decision table below shows four opposing courses of action arrayed against possible future states (which in this case are probable enemy capabilities/courses). Probabilities of the enemy courses can not be determined; therefore, the decision is made under uncertainty. The cell values are the payoffs of the outcomes. These values are dependent upon the measure of effectiveness. They could represent friendly units killed, friendly units disabled, relative damage of friendly/enemy forces, etc. Measuring the value in friendly units, the problem assumes that the payoffs are losses (the lower values are more advantageous).

| | $EC_1$ | $EC_2$ | $EC_3$ |
|---|---|---|---|
| COA 1 | 5 | 15 | 0 |
| COA 2 | 6 | 18 | 7 |
| COA 3 | 5 | 9 | 4 |
| COA 4 | 6 | 9 | 5 |

Notice that immediately COA 4 can be eliminated because COA 3 dominates COA 4 for all enemy capabilities (5<6, 9=9, 4<5). Using the minimax criterion COA 1: max=15; COA 2: max=8; COA 3: max=9. COA 2 would be selected because it represents the minimum of the maximum possible losses (worst case solution). The minimin criterion would select COA 1 since it represents the least of all possible minimum losses (0 is the minimum of 0, 4, and 7). Note that this is an optimistic viewpoint because if the enemy chose $EC_2$ then friendly forces would suffer the most losses - 15. The minimin criterion counts on the enemy selecting $EC_3$. The Laplace criterion requires the values to be averaged for each COA to find the expected outcome. In this example, COA 3 would be selected because it has the lowest average across the three enemy capabilities. An inherent danger here is that extremes are ignored. Any particular COA could have caused both the highest and lowest losses dependent upon the enemy capability; however, the average may turn out to be the "optimal" choice, given the Laplace criterion.

The operational commander can use the techniques and models of decision theory to aid in tough decisions. Although not discussed, there are several types of models available in addition to the decision table, to support the decision making process. They include decision trees, utility functions, and gaming theory. Each provide a quantitative basis for decision making. By no means does this mean that logic, experience, and common sense should be ignored. They key word is "basis" of decision; the "scientific answer" should not abdicate a decision maker of his responsibility to use his best judgement. The decision analysis techniques of operations research serve as a decision support tool for the operational commander. The next section demonstrates other "tools" of O.R. which can aid in problem solving and decision making.

## B. PROBLEM CATEGORIES

There are several categories of problems presented to the operational commander which require decisions and to which the techniques of operations research can be applied. A partial list includes resource allocation problems, inventory control requirements, detection problems, transportation and routing challenges, and queuing problems. Application of O.R. to these problems can aid the commander in many areas of his responsibility.

### (1) Resource Allocation

It is inevitable that there are never enough resources available to do all tasks to complete satisfaction. In many cases there are competing demands for scarce resources. The commander's ability to determine the most effective and efficient allocation of limited resources greatly enhances overall accomplishment of the objective. One technique available to the commander and analyst to help solve the resource allocation problem is linear programming. This is an optimization technique which means that the quantitative solution is not only feasible, but also optimal (ie, the best possible solution given the imposed constraints).

The step methodology applied to solve a problem using linear programming is as follows:

(1) Determine the objective: - (what resource does the commander need to minimize or maximize). In many classical cases, the objective is to minimize cost or maximize profit. In the operational context, it may be to minimize aircraft sorties to accomplish a mission or perhaps maximize ordinance delivered, given a limited number of sorties.

(2) Formulate the objective function: - (develop a mathematical representation of the objective).

(3) Determine the constraints placed on the problem and formulate. Using the aircraft example, typical constraints may be the number of aircraft available, or perhaps payload capacity of the aircraft, etc.

(4) Calculate: off-the-self computer packages are inexpensive, efficient and relatively easy to use.

(5) Analyze output and perform sensitivity analysis. - This is probably the most important. Without proper analysis, the quantitative results are meaningless.

Perhaps the best way to illustrate the value of linear programming is through a simplified example problem. (Note: This problem is hypothetical for illustrative purposes only. The numerical values are not necessarily representative of equipment capabilities).

A commander wants to move a light infantry battalion and supporting artillery to a forward position. His lift assets are limited and it is important that he optimize the aircraft hours so that lift assets can be available for other missions. He has four types of aircraft available: Hueys, Blackhawks, C Model Chinooks and D Model Chinooks. With these assets he must move: 600 troops, 40 jeeps, 20 trucks, and 6 artillery pieces. Given other priority commitments, only 6000 gallons of fuel are available for the mission. Also, Hueys, Blackhawks, C Models, and D Models are restricted to 30, 60, 40, 50 flight hours respectively. A further constraint of 150 total flight hours is also given. The following data is available:

| Aircraft | Flight Time(hrs) | Fuel(gals) per Flight | Lift Capability |
|---|---|---|---|
| Huey | 1.1 | 50 | 12 troops |
| Blackhawks | 1.0 | 60 | 12 troops, 1 jeep |
| C Model Chinook | 1.4 | 90 | a. 30 troops, 2 jeeps<br>b. 1 truck |
| D Model Chinook | 1.5 | 125 | a. 1 artillery piece<br>b. 30 troops, 2 jeeps<br>c. 1 truck |

(The formulation of this problem is at Annex A).

The objective of this problem is to minimize aircraft flight hours so that aircraft can be available for other missions.

The results of this problem show that the optimal resource allocation is to utilize all available D Model Chinook assets (34 sorties) and 13 C Model Chinook sorties, resulting in 77.8 flight hours and 5300 gallons of fuel utilized. That means that all Huey and Blackhawk assets, as well as 12 hours of C Model capability that were allocated to this mission, could now be utilized for other missions.

(2) Inventory Control

The modeling of inventory control requirements can aid the commander by insuring the proper resources are available at the proper time. By determining how much and when ammunition supplies, food, etc. should be replenished, he can insure that proper stockage levels are on hand, that quantities do not exceed storage capacities, and that resupply priorities are established. Consistent with knowing when and how much to replenish supplies is predicting when major end items or high priority replacement parts may break-down. Replacement analysis, which attempts to predict equipment failure, can help determine what the attrition levels will be (due to mechanical reasons, not combat losses) prior to hostilities commencing. This can provide additional information to the commander for both logistical and operational decisions.

(3) Queuing Problems

This type of analysis can also be referred to as a "waiting-line" problem and the solution requires a decision under risk (ie, a decision based on probability). If the demand for a service exceeds the capacity of a service facility, a queue will develop. Queuing analysis provides a mathematical solution to identify where lines are likely to occur based on a probable service rate. The objective of this analysis is to determine the best number of "facilities" in order to meet service requirement. A maintenance facility is a prime example for queuing analysis. A commander would want to know how many mechanics are needed and the number of repair bays that must be established in order to repair broken equipment. Too few mechanics or repair bays would cause waiting lines/backlog, thereby causing equipment to be delayed from being returned to an engagement. Conversely, too many mechanics would be a waste of valuable maintenance resources.

These problem categories just scratch the surface to provide an illustration of the power and value of operations research as an aid to the commander. Its value lays in the ability of the commander to make effective, efficient, and optimal decisions. The Soviets have a strong reliance on operations research to aid in the problem solving and decision making processes. The next chapter will discuss the pitfalls that can easily befall the user of operations research.

# CHAPTER 4

## PITFALLS

Just as the operational commander needs to be aware of the strengths and value of operations research, he needs to be aware of its limitations. These limitations include: technical problems caused by the inherent properties of the mathematical models/algorithms, poor problem identification, improper selection of measures of effectiveness, over-reliance on the quantitative solution, and poor analysis causing a misinterpretation of the results.

The first pitfall when applying operations research to problem solving can occur in the problem set-up. As mentioned earlier, the first step in the problem solving and decision making process is defining the problem. Recognizing that a problem exists or that the situation may cause a problem to surface in the future is not necessarily an easy task. Inherent in establishing the problem is selection of a measure of effectiveness (MOE) by which the outcomes are compared. Selection of the "wrong" MOE can lead to an erroneous decision. Using the WWII submarine versus convoy example presented in Chapter 2, the decision to implement larger convoys would have been different if the MOE selected was number of ships sunk per convoy rather than percentage of ships sunk. Since the number of ships sunk did not differ between larger and smaller convoys, the decision maker may not have chosen to utilize larger convoys. As discussed earlier however, the percentage MOE did show it to be more advantageous to convoy ships in larger numbers.

Selecting the wrong mathematical model for the problem to be solved can be a pitfall. This goes hand in hand with identifying the problem properly. Models are generally designed with specific purpose for a specific situation and utilize a specific set of assumptions. Attempting to use a model in a situation for which it was not designed can lead to improper decisions, due to the model incorporating assumptions which no longer apply, or due to the limitations (non robustness) of the model itself. "For example, the use of a force planning model for operational planning will generally produce unsatisfactory results. The force planning model is unable to give sufficient attention to major classes of data which are critical for development of operation use of current force and for which massive uncertainty exists relating to future forces."[16]

The next pitfall of O.R. is a paradox. The quantification of a problem is supposed to reduce uncertainty; however, sometimes the very nature of O.R. can increase uncertainty.

For example:

(1) The problem could be made more complex.

(2) The illusions of certainty can be destroyed.

(3) It can make clear what is specifically known and unknown.

(4) It can make the risk explicit by introducing probability.

(5) The more the analyst observes the cautions of science, the more his advice can be filled with doubts, assumptions, and conditional statements.[17]

The job of the analyst is to minimize these uncertainties when presenting recommendations to the decision maker. By performing sensitivity analysis on the solution, the analyst and decision maker can test the uncertainty and establish "confidence limits" on the solution.

The final pitfall to be discussed, and possibly the largest, is over-reliance on the quantitative solution. Because of some of the pitfalls mentioned above, it is important to insure that logic and common sense are applied to the solution/decision making process. The quantitative solution provides a basis; it does not negate the decision maker of his responsibility to exercise his judgement and experience in the decision process. The inherent exactness of number is contrary to the nature of war. It is difficult to quantify what Clausewitz calls "the fog of war." The Soviet's application of O.R. attempts to take O.R. to the extreme. Their theory seems to imply that the only reason there is a "fog of war" is because war is not fully understood. Once war is fully understood, it can be quantified. This does not pass the "reality test." "Unless you have been fighting the same enemy for a long time and are sure to keep fighting him, the next war will never be the one you have planned for."[18] The enemy will always try to outsmart, confuse, and surprise his opponent, thereby never allowing for the complete quantification of war. Although military science is a foundation for their doctrine, the Soviets seem to recognize the limits of quantification. they realize that much data is incomplete, random, and contradictory, and even false. They believe that the commander can overcome these difficulties by a skillful combination of creativity, art, boldness and cunning.[19] Even though the doctrinal concepts are different, when push comes to shove, the Soviets don't seem to be much different than Americans.

The above is not a complete enumeration of all possible pitfalls of O.R.; however, it does identify the necessity of being aware of O.R.'s limitations.

# CHAPTER 5

## CONCLUSIONS - WHAT THE OPERATIONAL COMMANDER REALLY NEEDS

A brief history of operations research has been presented, along with the strengths and limitations of O.R. The Soviet view of operations research has been illuminated and specific types of problems and techniques have been illustrated to show the value of operations research to the operational commander. But what does it all boil down to; what is it that the commander really needs?

The commander needs to receive good advice and recommendations. The analyst can help by identifying the real problem and establishing appropriate MOEs by which to evaluate alternatives. He can provide the technical knowledge, insure pitfalls are avoided, and help the commander understand the conditions under which a course of action is workable.

The commander needs a feasible solution - one that will work. Although the optimal decision is preferable, it is not always necessary. The analyst should eliminate the "non-starters" from the spectrum of alternatives and help the commander find roughly the right courses of action. The commander should be provided with, and ask for, the sensitivity of his possible alternatives. (How will changes in the situation affect the alternatives).

The commander needs a timely analysis of his alternatives and a timely solution to his problems. A 100% solution which is too late to affect the decision is no good. Therefore, the "80% solution" performed in a timely manner can provide the quantitative basis for the commander's action.

Most important, the commander needs the quantitative solution to be put into perspective. Common sense and experiential knowledge must be applied. The analyst with operational experience must maintain reality in his analysis and communicate his findings to the commander so that the most effective decisions can be made. Conversely, the operational commander must be aware of the strengths and limitations of O.R.so that he can ask the "right" questions.

Operations research can be a valuable tool to the commander by providing that <u>quantitative</u> basis for operational planning, organizing and executing operations; however, the "<u>art</u>" will never be removed from the concept of "operational art."

## ANNEX A

## LINEAR PROGRAMMING EXAMPLE FORMULATION

Decision Variables

$X_1$ = Huey Sorties
$X_2$ = Blackhawk Sorties
$X_3$ = C Model Chinook (Capability a)
$X_4$ = C Model Chinook (Capability b)
$X_5$ = D Model Chinook (Capability a)
$X_6$ = D Model Chinook (Capability b)
$X_7$ = D Model Chinook (Capability c)

Objective - Minimize Flight Hours

Objective Function:

$$\text{MIN } Z = 1.1X_1 + 1.0X_2 + 2.2X_3 + 2.2X_4 + 1.5X_5 + 1.5X_6 + 1.5X_7$$

Subject to Constraints:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Troops | $12X_1$ | $+ 12X_2$ | $+ 30X_3$ | | | $+ 30X_6$ | | $\geq$ | 600 |
| Jeeps | | $1X_2$ | $+ 2X_3$ | | | $+ 2X_6$ | | $\geq$ | 40 |
| Trucks | | | | $1X_4$ | | | $+ 1X_7$ | $\geq$ | 20 |
| Artillery | | | | | | | $1X_7$ | $\geq$ | 6 |
| Huey Hrs | $1.1X_1$ | | | | | | | $\leq$ | 30 |
| Blkhawk Hrs | | $1.0X_2$ | | | | | | $\leq$ | 60 |
| C Model Hrs | | | $2.2X_3$ | $+2.2X_4$ | | | | $\leq$ | 40 |
| D Model Hrs | | | | | $1.5X_5$ | $+1.5X_6$ | $+1.5X_7$ | $\leq$ | 50 |
| Total Hrs | $1.1X_1$ | $+1.0X_2$ | $+2.2X_3$ | $+2.2X_4$ | $+1.5X_5$ | $+1.5X_6$ | $+1.5X_7$ | $\leq$ | 150 |
| Fuel | $50X_1$ | $+ 60X_2$ | $+ 90X_3$ | $+ 90X_4$ | $+125X_5$ | $+125X_6$ | $+125X_7$ | $\leq$ | 6000[20] |

## ENDNOTES

1. 2:cover

2. 14:14

3. 14:15

4. 6:4

5. 10:3

6. 1:11

7. 9:207

8. 9:212

9. 9:212

10. 5:10

11. 5:10

12. 15:61

13. 15:63

14. 12:26

15. 15:67

16. 3:11

17. 11

18. 1:10

19. 9:213

20. Original problem which was derived from a problem presented in NWC Elective, Decision Tools and Techniques.

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